

TITLE: FUTURE LAMPF EXPERIMENTS ON LEPTON-NUMBER NONCONSERVATION

MASTER

AUTHOR(S): Richard E. Mischke

DISCLAIMER

SUBMITTED TO: Neutrino-81 Proceedings

University of California

By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes.

The Los Alamos Scientific Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.



LOS ALAMOS SCIENTIFIC LABORATORY

Post Office Box 1663 Los Alamos, New Mexico 87545

An Affirmative Action/Equal Opportunity Employer

FUTURE LAMPF EXPERIMENTS ON LEPTON-NUMBER NONCONSERVATION

R. E. Mischke
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

ABSTRACT

Planned experiments at LAMPF involving neutrinoless processes which are sensitive to lepton-number nonconservation are discussed with emphasis on the Crystal Box program.

Most talks at this conference involved neutrinos in one way or another. In the previous talk, current and future neutrino experiments at LAMPF were discussed. In addition, there are several neutrinoless experiments which are underway at LAMPF, and it is the absence of neutrinos that makes them probes of lepton-number nonconservation.

The processes being sought are listed in Table I along with present limits on their occurrence. In addition to the experiments at LAMPF, the other meson factories are active in this field. A previous talk by M. Blecher described the experiment at TRIUMF to search for $\mu \rightarrow e$ conversion in the field of a nucleus. At SIN, a new detector called SINDRUM is planned which will be optimized for μ decay experiments, especially $\mu \rightarrow eee$.

Figure 1 shows the progress which has been made in the last 3-1/2 decades in setting limits on these processes. Note the pattern of limits for the process $\mu \rightarrow e\gamma$, whose absence played a crucial role in formulating the notion of lepton-number conservation. This notion was generally accepted following the two-neutrino experiment in 1962. The figure shows clearly how much progress was made in the years near 1960 before interest in $\mu \rightarrow e\gamma$ waned with no new experiments for 10 years between 1965 and 1974. It is coincidental that the rumored observance of $\mu \rightarrow e\gamma$ at the level of 10^{-8} prompted a rethinking of the question of lepton-number conservation. While the rumor proved false, now it is generally accepted that lepton number need not be conserved.

The literature on this subject is vast and an interested reader is referred to one of the bibliographies which has been compiled, for example see refs. 1 and 2. A relevant question for this conference is to ask whether a definite connection can be made between neutrino mass, neutrino oscillations, and flavor-changing muon processes. Unfortunately, given the various types of models under consideration today, the answer is no.

In the "standard" Glashow-Weinberg-Salam model, conservation of lepton number is assumed and the neutrinos are massless.³ Minimal extensions of this model include left-right symmetric models, inclusion of doubly-charged leptons, or additional Higgs doublets. The predictions of these models for flavor-changing lepton processes vary widely but often it is easy to obtain values near present experimental limits. The relative rates for different processes are not standard. For example, with doubly charged leptons,⁴ the rate for $\mu \rightarrow 3e$ can be 1000 times that for $\mu \rightarrow e\gamma$ in contrast to the internal conversion process which gives the rate for $\mu \rightarrow 3e$ only 1% of that for $\mu \rightarrow e\gamma$.

Lepton-number nonconservation and neutrino masses⁵ usually come via heavy intermediate particles which can be fermions or bosons and whose masses are not fixed. In most cases there is no definite prediction for either the size of neutrino masses or the magnitude of flavor-changing lepton processes.

Grand unified theories generally predict massive neutrinos and lepton number nonconservation. In SU(5) the neutrinos can be massless but it is not required.⁶ Lepton-number nonconserving processes may be too rare to be observable. With SO(10) the situation could be more favorable for experimentalists with $m_\nu \sim 1$ eV and rates for rare muon processes near experimental limits.⁷ Other models such as horizontal symmetries or composite models have been proposed. One horizontal symmetry model predicts lepton-number violation with measurable rates for flavor-changing processes but the neutrinos remain massless.⁸

It seems characteristic of models that they have free parameters which allow branching ratios just below the level thus far examined. Thus, it is worth noting that the technicolor models ran into difficulty partly because they expected too large rates for flavor-changing processes and they are now disfavored.⁹

One conclusion to be drawn from an examination of models is to confirm the claim that neutrino mass, neutrino oscillation, and neutrinoless experiments must all be pursued. The breadth of theoretical models under consideration does not permit selection of one or two crucial experiments. However, it is characteristic of these flavor-changing experiments that the exchanged intermediate particles have masses in the range of a few hundred GeV if the branching ratios or rates are presently measurable. Turning the statement around, these experiments are one of our best probes of effects due to a mass scale between 10^2 and 10^{15} GeV. It is in this atmosphere of theoretical uncertainty and expectation that a new round of experiments is underway.

A schematic diagram of the Crystal Box detector is shown in Fig. 2. It is being constructed by a collaboration from the Los Alamos National Laboratory, the University of Chicago, and Stanford University. Muons from a surface muon beam will stop in a thin extended target at the center of a cylindrical drift chamber. The drift chamber has eight concentric layers of cells and is surrounded by 396 NaI (Tl) crystals. Between the drift chamber and the crystals, a layer of 36 scintillation counters serves both as a bank of veto counters for the crystals and a trigger for electrons from muon decay.

Data will be taken simultaneously to search for $\mu \rightarrow e\gamma$, $\mu \rightarrow e\gamma\gamma$, and $\mu \rightarrow eee$. Assuming a stopping rate of 5×10^5 μ/s , the limits which can be reached with 90% confidence as a function of running time are shown in Fig. 3. These results depend on the resolution properties of the detector. Most of the relevant parameters have been measured and are listed in Table II. The major components of this experiment should be assembled before the end of this year and data taking will begin next year.

There are other experiments planned at LAMPF to search for $\mu \rightarrow e$ conversion in the field of a nucleus. One plans to search for $\mu^- \rightarrow e^+$ on ^{88}Sr using radiochemical techniques. This experiment by a group from the University of Chicago, Lakehead University, and Los Alamos plans to reach 10^{-12} by observing a very specific decay chain $^{89}\text{Kr} \rightarrow ^{89}\text{Rb}$. At present, they are checking the detection scheme by looking for Δ^{++} production in the reaction $n^{88}\text{Sr} \rightarrow ^{89}\text{Kr} + \Delta^{++}$. Later they would run on-line in a stopped muon beam.

Another LAMPF experiment to search for $\mu^- \rightarrow e^-$ conversion in the field of a nucleus by a group from Yale, University of Pennsylvania, and SIN involves a superconducting solenoid with a drift chamber detector (Fig. 4). They will use a cloud μ^- beam with a stopping rate of order $5 \times 10^5 \mu^-/\text{s}$, probably using Argon as a target. Sufficiently energetic electrons will be detected on a TPC-like end cap. This experiment aims for a limit of 10^{-12} and is one-to-two years away.

Further in the future, another attack on $\mu \rightarrow e\gamma$ is planned at LAMPF using the detector arrangement shown in Fig. 5. The NaI crystals from the Crystal Box will be rearranged into a wall, and if funds are available, a second wall will be added. This experiment is expected to reach a branching ratio limit of at least 10^{-12} . (See the line labeled $\mu \rightarrow e\gamma$ (III) in Fig. 3.)

These are the experiments which have been proposed and accepted at this time. The results may be just to lower limits on these processes by one or more orders of magnitude. However, we can be optimistic that at some future neutrino conference, there will be a nonzero result to report.

I would like to thank my colleagues for discussions, particularly C. M. Hoffman and T. Goldman. This work is supported by the U. S. Department of Energy.

References

1. H. K. Walter, SINDRUM Note 1, ETH Zürich (November 1980).
2. O. Shanker, TRI-PP-81-10, TRIUMF (March 1981).
3. S. Weinberg, Phys. Rev. Lett. 19, 1264 (1967); A. Salam, Proceedings of the 9th Nobel Symposium, ed. N. Svartholm (Almquist and Wicksells, Stockholm, 1968); S. Glashow, J. Iliopoulos, and L. Maiani, Phys. Rev. D2, 1285 (1970).
4. F. Wilczek and A. Zee, Phys. Rev. Lett. 38, 531 (1977).
5. T. P. Cheng and L-F Li, Phys. Rev. D 22, 2860 (1980).
6. R. Barbieri, J. Ellis, and M. K. Gaillard, Phys. Lett. 90B, 249 (1980).
7. Riazuddin, Weak Interactions as Probes of Unification (VPI-1980), eds. G. B. Collins, L. N. Chang, and J. R. Ficenec (Am. Inst. of Physics, New York, 1981) p. 21.
8. A. Davidson, Phys. Lett. 90B, 87 (1980).
9. G. L. Kane, Weak Interactions as Probes of Unification (VPI-1980), eds. G. B. Collins, L. N. Chang, and J. R. Ficinec (Am. Inst. of Physics, New York, 1981) p. 257.

Table I. Lepton number nonconservation via neutrinoless muon processes

<u>Mode</u>	<u>Present Limit</u> ^a (90% confidence)
$\mu \rightarrow e \gamma$	$< 1.7 \times 10^{-10}$
$\mu \rightarrow e e e$	$< 1.9 \times 10^{-9}$
$\mu \rightarrow e \gamma \gamma$	$< 5 \times 10^{-8}$
$\mu^- A \rightarrow e^- A$	$< 7 \times 10^{-11}$ (on sulphur)
$\mu^- A \rightarrow e^+ A^{(Z-2)}$	$< 3 \times 10^{-10}$ (on iodine)

^aThe first three entries are branching ratio limits and the last two are capture rates relative to normal μ capture on the given nucleus.

Table II. Crystal box resolutions

Scintillator Timing	0.28 ns FWHM
NaI Timing	0.54 ns FWHM
Energy	< 6 % FWHM
Position	< 1.6 cm rms
Drift Chamber Position	< 150 μ m rms

Figure Captions

1. Limits on various rare muon processes versus time.
2. Schematic diagram of the Crystal Box detector.
3. Predicted limits on rare muon decays versus running time with the Crystal Box detector.
4. Schematic diagram of the detector for the $\mu^- \rightarrow e^-$ search.
5. Schematic diagram of the detector for a later $\mu \rightarrow e\gamma$ experiment.

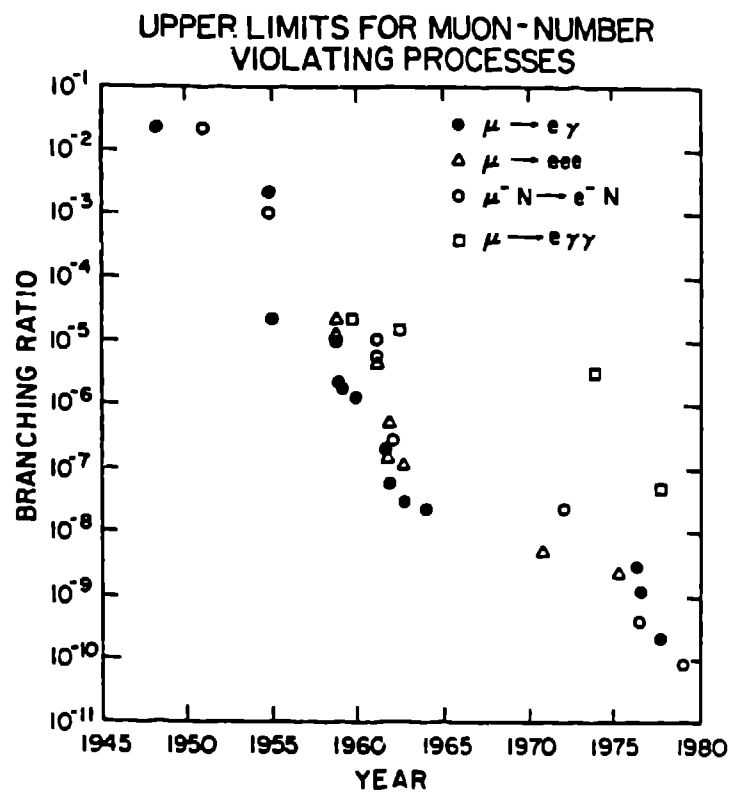


Fig. 1.

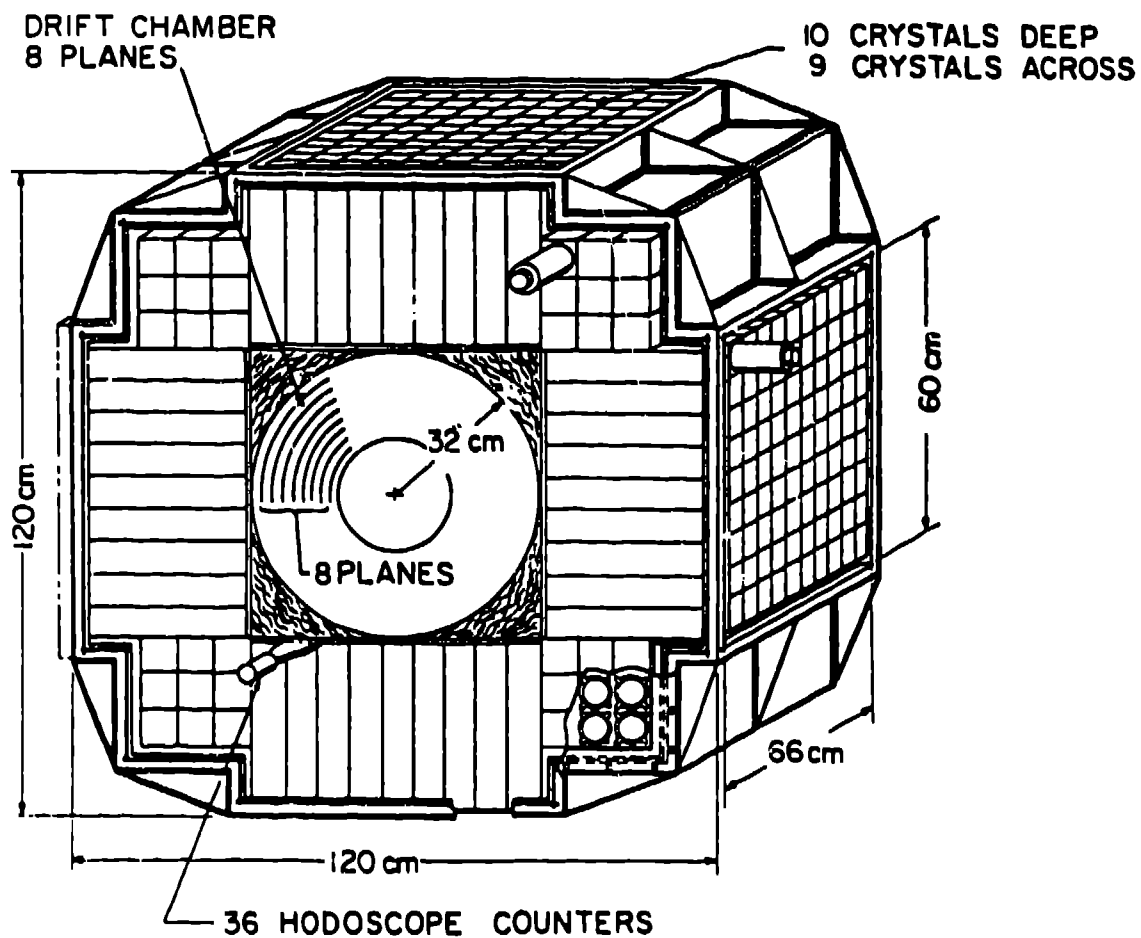


Fig. 2.

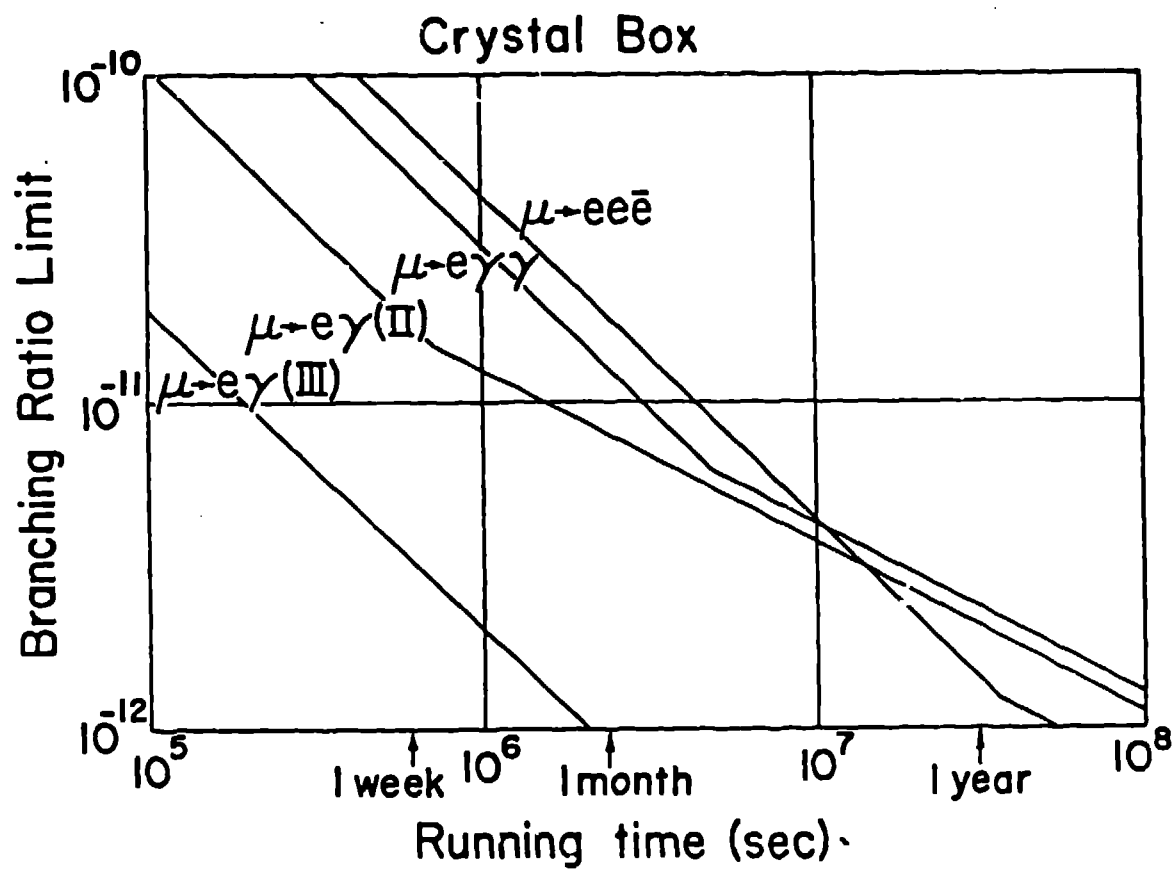


Fig. 3.

Experimental Arrangement for $\mu^- + e^-$ Conversion

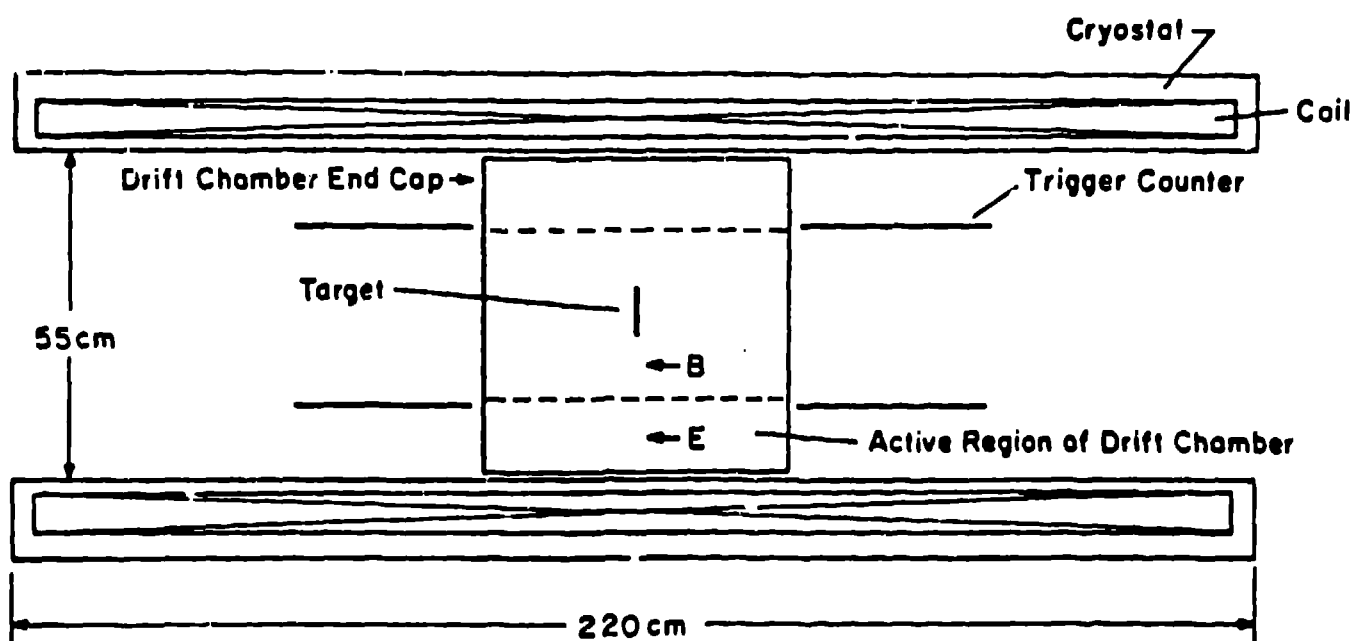


Fig. 4

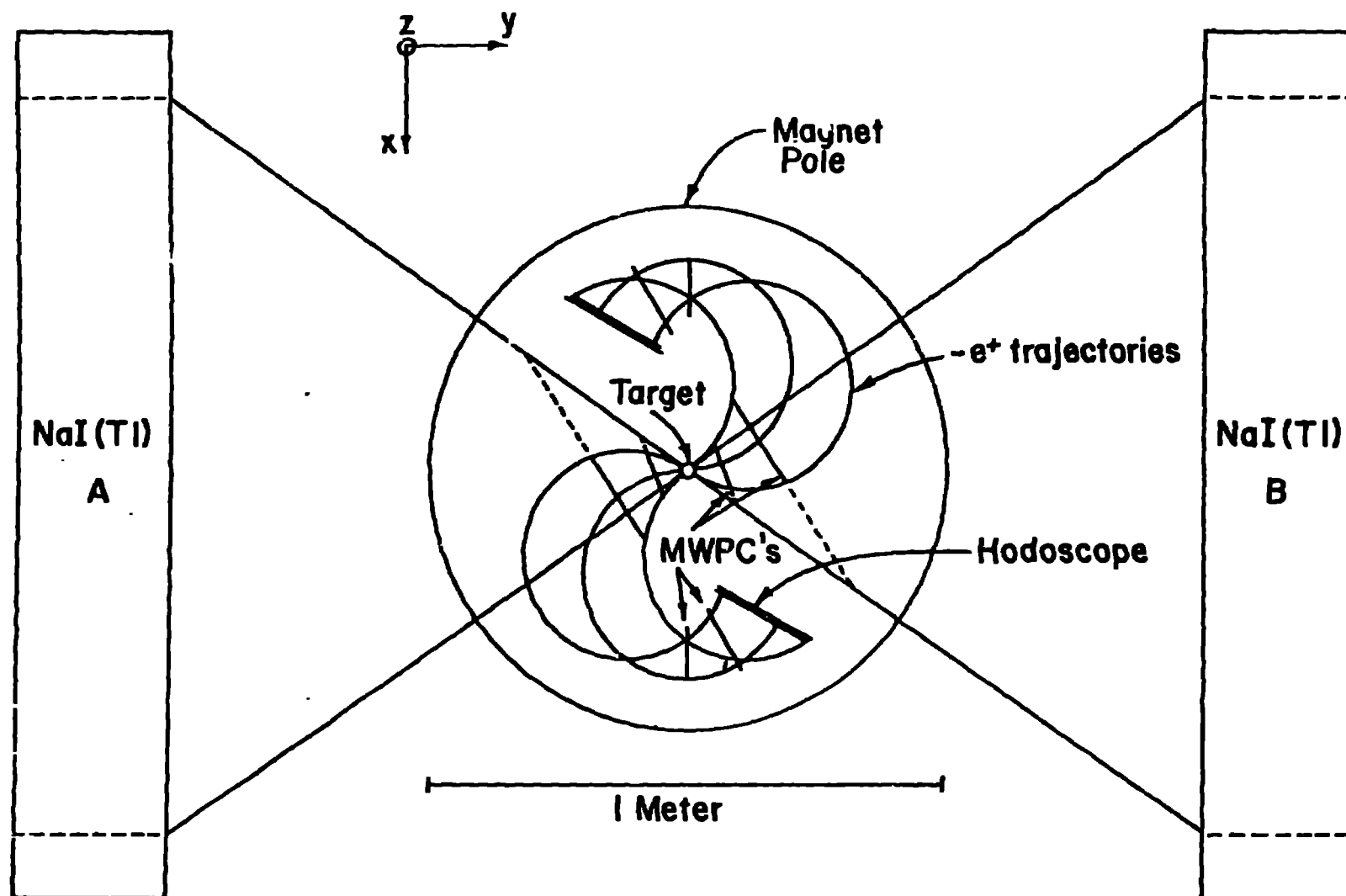


Fig. 5.